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A VIBROGRAPHIC STUDY OF THE OUTPUT OF A SINGLE-PHASE HALF-WAVE POWER RECTIFIER

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ABSTRACT. A simple device for studying the efficacy of design of filter circuits employed in power units is described. Instead of the usual cathode-ray oscillograph and a linear time base, the arrangement consists of an electromagnetically excited wire, the vibrations being recorded by a vibrograph, devised by the author (Tirunarayanachar, 1932). Vibrograms taken in the study of the wave-form and ripple-components of a single phase half-wave power rectifier output are given in support of the method suggested. The arrangement is specially suited for studying the ripple components in the output. The applicability of the method in wave-form investigation is being further studied.

INTRODUCTION

A thermionic rectifier allows a current flow in one direction only and offers infinite resistance to the current flow when the polarity is reversed; so that if the input current is a symmetrical A.C. of the form $I_0 \sin \omega t$ ($\omega = 2\pi f$, where f is the frequency of the supply mains), then the output from a single-phase half-wave rectifier is a current of the form:

$I = I_0 \sin \omega t$ between $t = 0$ to $t = \frac{T}{2}$; the output current is zero from $t = \frac{T}{2}$ to $t = T$.

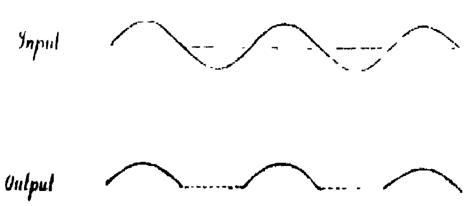

FIG. 1

In order to get a detailed picture of the output current, it must be resolved into its various components by the application of Fourier's theorem. $f(x)$ can be represented by the infinite series:

$$f(x) = A_0 + \sum_{n=1}^{\infty} A_n \cos nx + \sum_{n=1}^{\infty} B_n \sin nx,$$

where

$$A_0 = \frac{1}{T} \int_0^T f(x)\, dx$$

$$A_n = \frac{2}{T} \int_0^T f(x) \cos nx\, dx$$

$$B_n = \frac{2}{T} \int_0^T f(x) \sin nx\, dx,$$

In this case $f(x)=I_0 \sin \omega t$ between the limits $t=0$ to $t=\frac{T}{2}$; $f(x)=0$ between $t=\frac{T}{2}$ and $t=T$. On evaluating the Fourier coefficients for all values of n from 1 to ∞ by working out the definite integrals given above, we get for the instantaneous value of the rectified output current I, the result :

$$I=I_0\left[\frac{1}{\pi}+\tfrac{1}{2}\sin \omega t-\frac{2}{3\pi}\cos 2\omega t-\frac{2}{15\pi}\cos 4\omega t-\ldots\ldots\right].$$

The analysis shows that the rectified output consists of a D.C. of value I_0/π having superposed upon it an A.C. of supply frequency and having amplitude $I_0/2$ together with a series of even harmonics whose amplitudes go on decreasing rapidly.

A cathode-ray oscillograph together with a linear time-base is generally used for studying the wave-form of such output current. This paper gives an account of the results obtained by a study of the output current using a sonometer in conjunction with a vibrograph.

EXPERIMENTAL ARRANGEMENT AND RESULTS

Fig. 2 shows the experimental arrangement employed in the study of the problem. The rectifier used was a Tungar rectifier. It is a soft valve rectifier similar to that of a mercury vapour rectifier: but the tube in a Tungar contains pure argon gas at a pressure of three to eight cm. of mercury column. The tube operates at a low voltage and can handle large currents. A small current from the output of such a rectifier is passed through a sonometer wire AB. A portion of the wire lies between the poles N, S, of a permanent magnet mounted so that it can be slid along the length of the wire. When the frequency of anyone of the ripple components in the output coincides with one of the possible harmonic frequencies of the wire, a large resonant vibration occurs. The point of observation is illuminated by the source S_1 and the optical system L_1. L_2 focuses the shadow on the slit of the vibrograph, immediately behind which is the photographic plate shot at right angles to the direction of vibrations. Tuning can be effected by varying the tension and length of the wire. The method is a very elegant one and by suitably placing the permanent magnet,

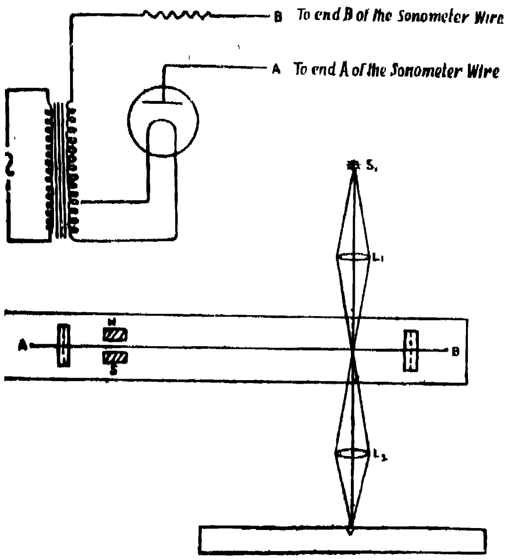

FIG. 2

i.e., by the proper control of the point of mechanical excitation of the wire, it is easy to obtain resonance with the ripple components in the output. Curves F, G, in the plate indicate vibrograms obtained in that way and they correspond to frequencies f and $2f$.

Strings excited by electromagnetic means have in the past been utilised for the study of symmetrical audiofrequency currents, notably by D. W. Dye (1924) in the design of a standard sonometer. The vibrographic records taken by the author seem to suggest that the method can also be applied for the study of assymetrical currents as in the case of the output of single-phase half-wave rectifier.

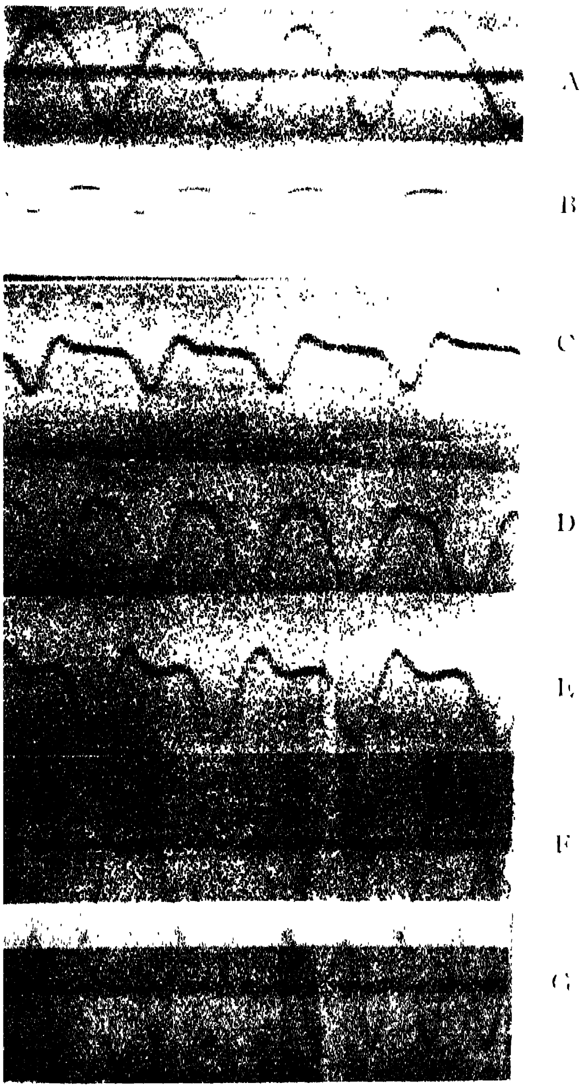

FIG. 3

In taking a vibrogram care must be taken in choosing the point of excitation as well as the point of observation on the wire. All harmonics which have a node at the point of excitation will be absent from the resultant form. Since the amplitudes of the higher harmonics go on rapidly decreasing, their effect on the wave-form becomes small, beyond a certain number. Curve A is the wave-form of the input symmetrical A.C. Curves B, C, D and E represent the wave-form of the rectified output, the point of observation is different in each case for a chosen point of excitation. Curves C and E show the assymetric effect remarkably well. The lower halves of the curves correspond to the half period when there is no current through the wire; on account of the inertia of the vibrating system, those parts are present.

CONCLUSION

In conclusion, the author wishes to suggest that besides the study of the wave-form, the arrangement is particularly suitable for testing the efficiency of filter circuits designed for smoothing the raw output of an H. W. rectifier. The power required for excitation of the wire in the case of a properly designed instrument like the Dye standard sonometer is of the order of only one milliwatt, for giving visible loops at lower frequencies. It is enough if the test is conducted for the presence of the fundamental ripple component only, for if the filter is designed to cut off the fundamental ripple component from the output, it would be a more efficient filter in cutting off the higher harmonic components.

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